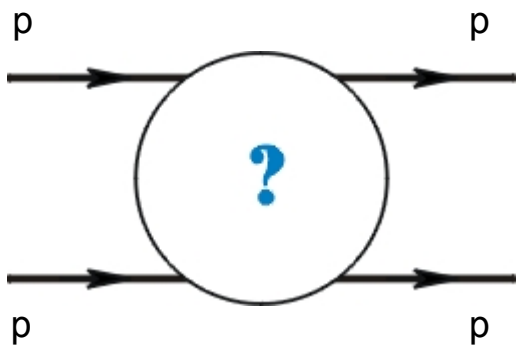
Physics with Tagged Forward Protons at RHIC

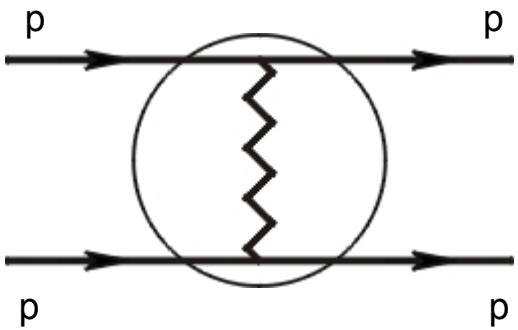
Włodek Guryn
Brookhaven National Laboratory, Upton, NY, USA

1. Introduction - (qualitative) description of the processes;
2. What can be done at RHIC?
3. Implementation;
4. Summary.

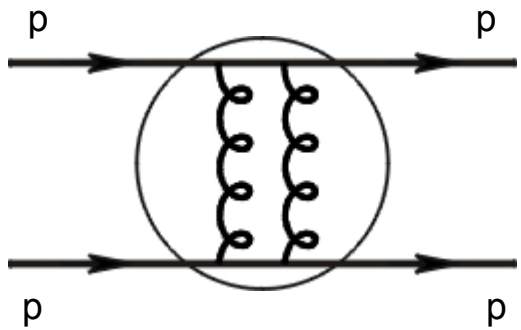
Physics Processes I



In t-channel it is an exchange with quantum numbers of vacuum

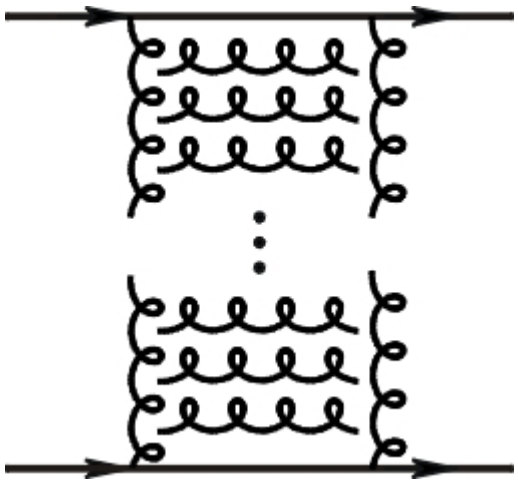


Non Pert. QCD

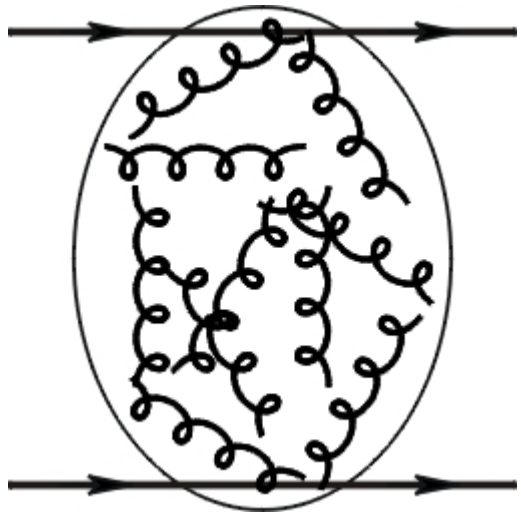


PQCD picture

Physics Processes II



Gluon Ladders

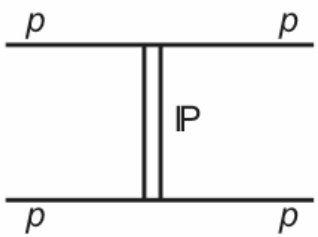


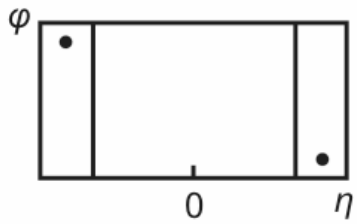
Gluonic Exchanges

These processes are mediated by gloun rich exchanges

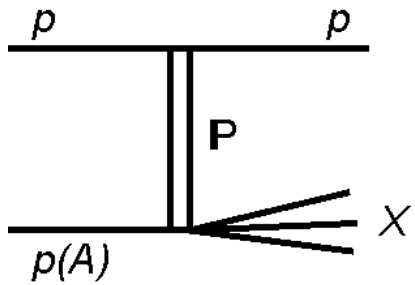
Elastic and Inelastic Processes

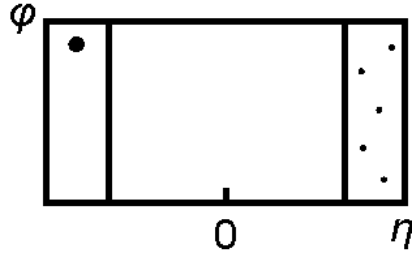
Elastic Scattering



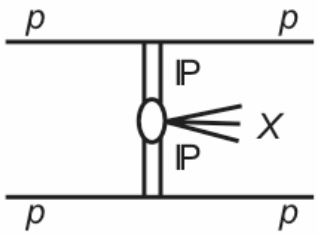


Single Diffraction





Central Production



For each proton vertex one has

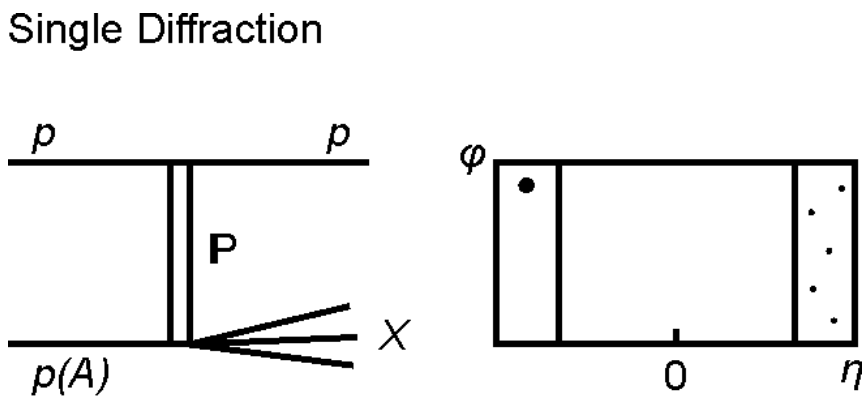
t four-momentum transfer

$\xi = \Delta p/p$

$\mathbf{M_X}$ invariant mass

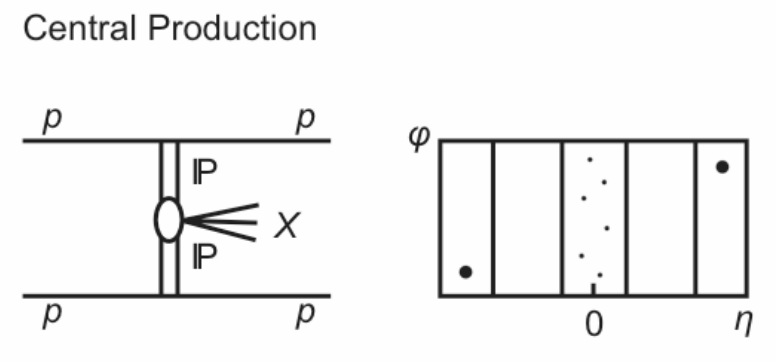
In terms of QCD, Pomeron exchange consists of the exchange of a color singlet combination of gluons. Hence, triggering on forward protons at high (RHIC) energies predominantly selects exchanges mediated by gluonic matter.

p(d)A Scattering



1. Study dependence on A and beam polarization of inclusive diffraction in p(d)A→ pA.
2. Due to spectator effects in deuteron Nucleus collisions dA→pX the p_T spectrum of the outgoing proton shows a clear diffractive pattern because of the absorption of the center of incoming wave [B.K.].
3. One can also study the size of the rapidity gap in the same reaction, where the size of the "rapidity gap" reflects the different contributions of various Fock configurations of the proton that scatters through the color field of the nucleus [R.V.].

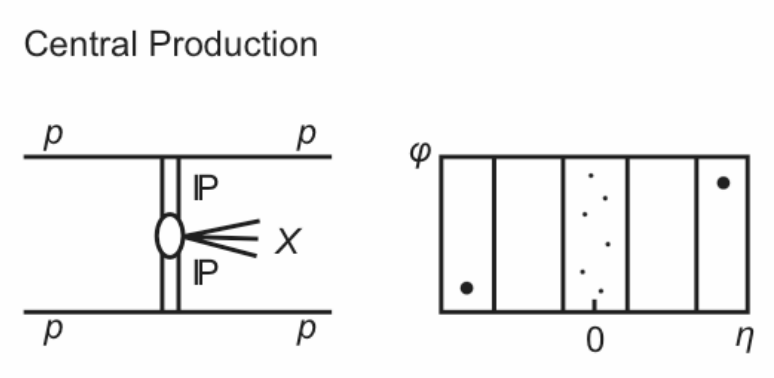
Central Production in DPE



In the double Pomeron exchange process each proton “emits” a Pomeron and the two Pomerons interact producing a massive system M_X.

The massive system could form resonances or consist of jet pairs. Because of the constraints provided by the double Pomeron interaction, glueballs, and other states coupling preferentially to gluons, will be produced with much reduced backgrounds compared to standard hadronic production processes.

Glueball Central Production in DPE



The idea that the production of glueballs is enhanced in the central region in the process pp $\rightarrow$ pM_Xp was first proposed by F.Close and was demonstrated by WA102 expt.

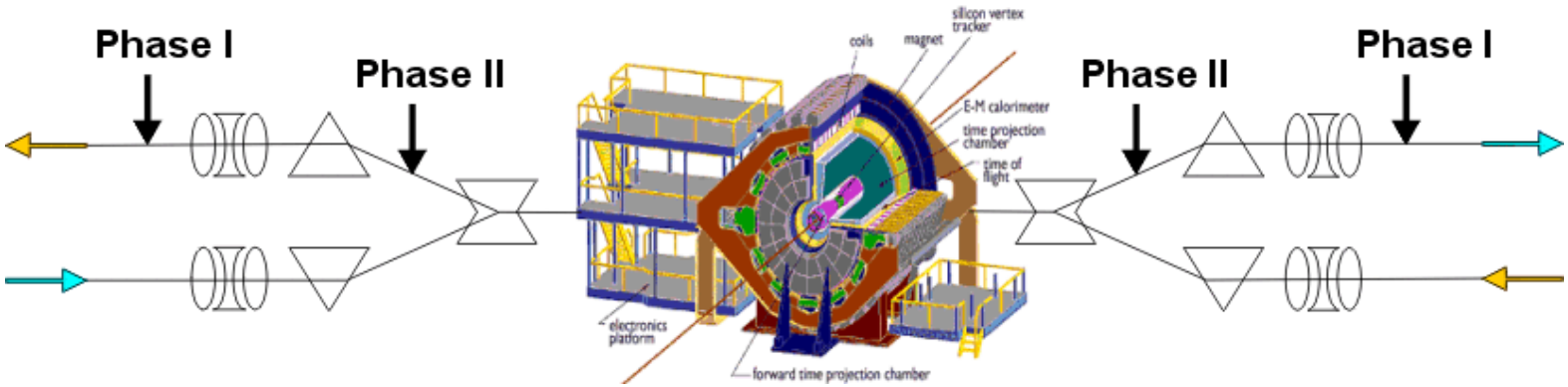
The pattern of resonances produced in central region depends on:

$$dP_T \equiv \left| \bar{k}_{T1} - \bar{k}_{T2} \right|$$

When $dP_T \geq \Lambda_{QCD}$ $\bar{q}q$ states are prominent and when dP_T is small the surviving resonances include glueball candidates.

Implementation at RHIC

Need detectors to tag forward protons and detector with good acceptance and particle ID to measure central system



Roman Pots of pp2pp and STAR

Physics with Tagged Forward Protons with the STAR Detector at RHIC

H. Spinka
Argonne National Laboratory, USA

R.E. Chrien, R. Gill, W. Guryn*, B. Hackenburg, J. Landgraf, T.A. Ljubičič, D. Lynn, C. Pearson, P. Pile, S. Tepikian, K. Yip
Brookhaven National Laboratory, USA

A. A. Bogdanov, S.B. Nurushev, M.F Runtzo
Moscow Engineering Physics Institute (MEPHI), Moscow, Russia

I. G. Alekseev, V. P. Kanavets, L. I. Koroleva, B. V. Morozov, D. N. Svirida
ITEP, Moscow, Russia

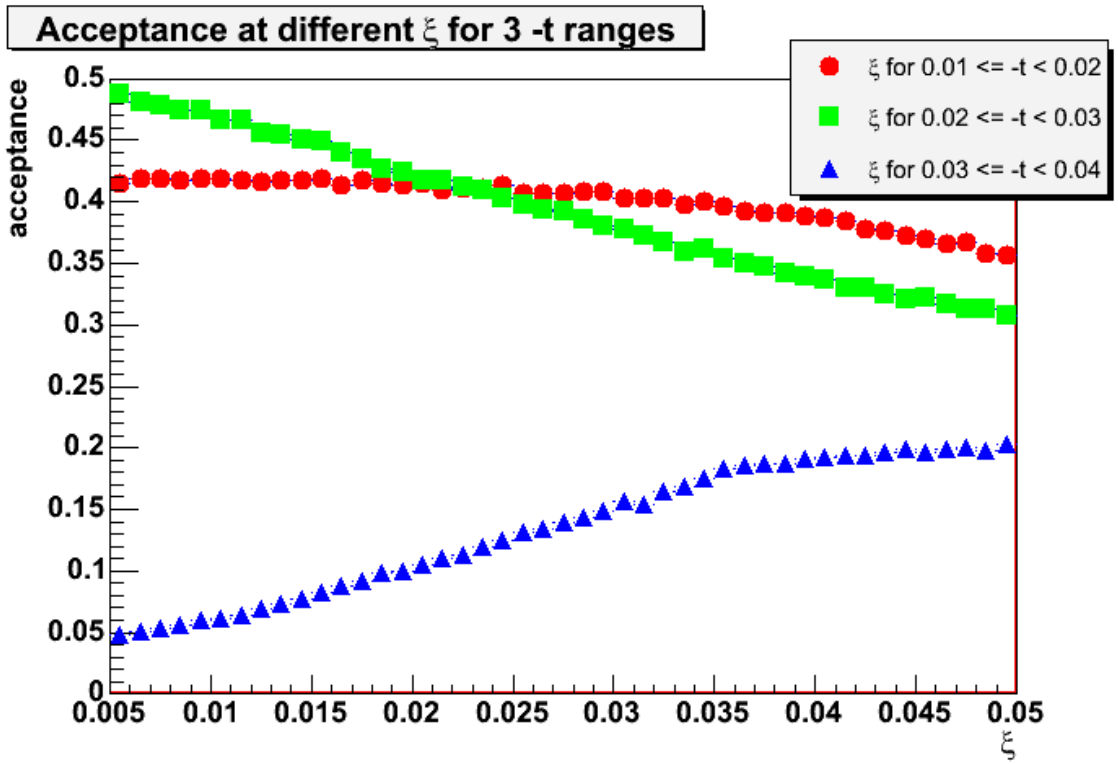
B. Surrow
MIT, Boston USA

S. Khodinov, M. Rijssenbeek
SUNY Stony Brook, USA

A.Sandacz
Soltan Institue for Nuclear Studies, Warsaw, Poland

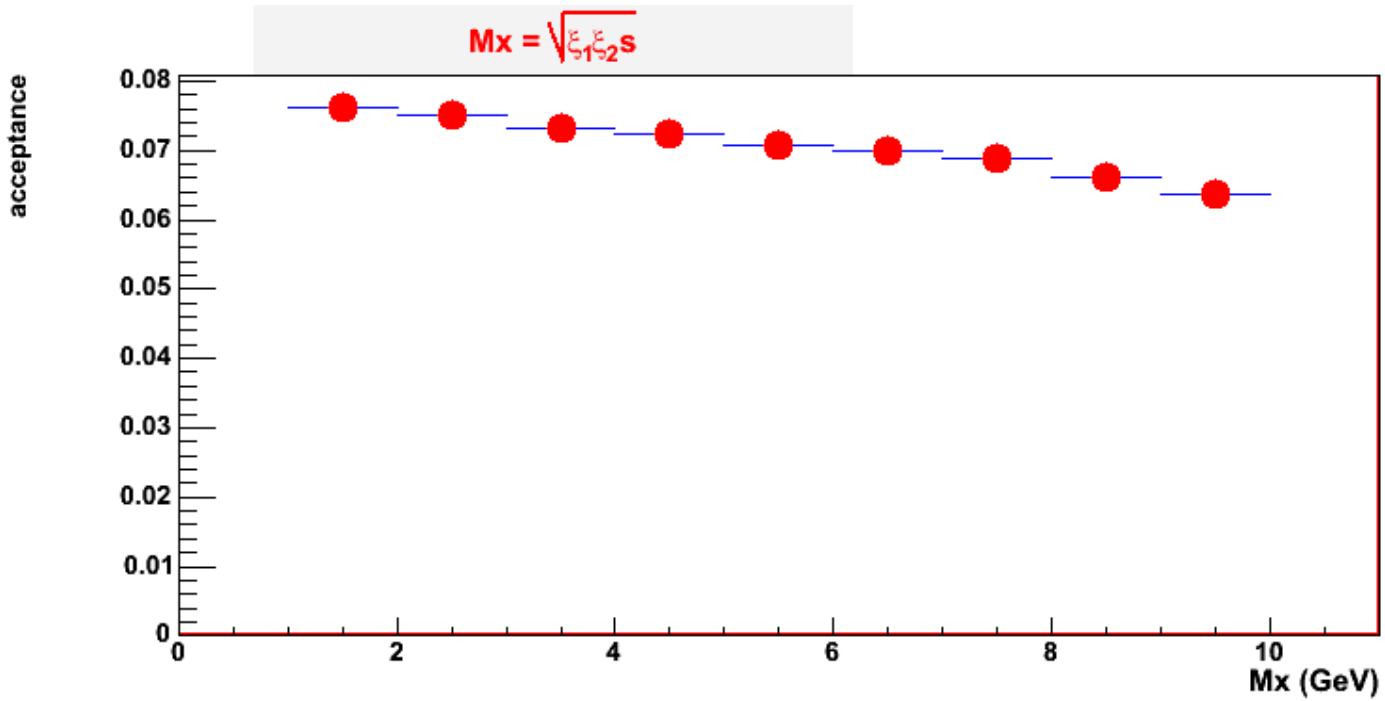
*Contact person
E-mail guryn@bnl.gov
Phone (631) 344 3878

Acceptance Studies SDD



Single proton in the Roman Pot

Acceptance Study DPE



Two protons are detected

Reconstruction of the Momentum Loss ξ

1. Need to measure vector at the detection point, hence two RPs are needed on each side of STAR.
2. For a proton, which scatters with Θ and ξ we have:

$$x_1 = a_1 x_0 + L_1 \Theta_x + \eta_1 \xi; \quad \textbf{detection point 1}$$
$$x_2 = a_2 x_0 + L_2 \Theta_x + \eta_2 \xi; \quad \textbf{detection point 2}$$

$\Leftarrow$ Accelerator transport

$$\begin{pmatrix} \Theta_x \\ \xi \end{pmatrix} = \frac{1}{Det} \begin{pmatrix} \eta_2; & -\eta_1 \\ -L_2; & -L_1 \end{pmatrix} \begin{pmatrix} x_1 - a_1 x_0 \\ x_2 - a_2 x_0 \end{pmatrix}$$

Running Scenario for Phase I

Important conditions:

- One event in the TPC per proton pair in RPs $\Rightarrow$ "low luminosity";
- Alignment is very important $\Rightarrow$ use elastic events;
- Need to reach small t and ξ values $\Rightarrow$ large β^*=20m.

Hence a dedicated three-day run is preferable

The setup time of the β^*=20 m optics is estimated to be 12 hours.

With 40 hrs data taking, luminosity 2×10^{29} cm^{-2}sec^{-1} $\Rightarrow$ $2\cdot10^5$ DPE events.

Summary

The physics program of tagged forward protons with STAR at RHIC can:

1. Study standard hadron diffraction both elastic and inelastic and its spin dependence in unexplored t and $\sqrt{s}$ range;
2. Study the structure of color singlet exchange in the non-perturbative regime of QCD.
3. Search for central production of light and massive systems in double Pomeron exchange process - glueballs.
4. Search for an Odderon - an eigenstate of CGC.
5. At RHIC II one would take advantage of smaller TPC, include more coverage to better characterize rapidity gaps.

Those studies will add to our understanding of QCD in the non-perturbative regime where calculations are not easy and one has to be guided by measurements.

There is a great potential for important discoveries

Proton Trajectory